SPATIAL DIVISION MULTIPLE ACCESS PERSONAL COMMUNICATION SERVICES

ESPRIT

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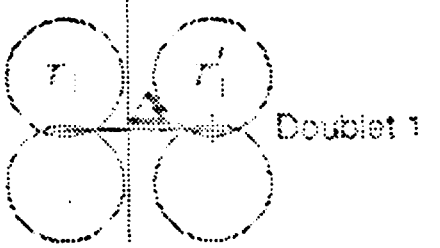


SDMA AND WIRELESS COMMUNICATIONS
INCREASING CAPACITY AND QUALITY

THE CAPACITY PROBLEM

- In major metropolitan areas, current demand for wireless information transmission exceeds capacity.
- Most projections indicate exponential growth in demand over the next decade or two.
- There is only a limited amount of (frequency) spectrum available, and there is a limit to the amount of information that can be transmitted over the current (and future) channels.
- Proposed concepts for handling increased demand such as:
  - decreasing service area per base station and adding more base stations (microcells) are costly, involving increased hardware, maintenance, and lease costs.
  - changing modulation format from analog to digital allowing exploitation of source coding/compression techniques are costly and incompatible with current systems.
- A technique for increasing capacity is required which is:
  1. compatible with all modulation types, digital or analog,
  2. modular and therefore easily expandable,
  3. and reliable.

SDMA AND WIRELESS COMMUNICATIONS
INCREASING CAPACITY AND QUALITY

THE QUALITY PROBLEM

- In major metropolitan areas, the RF environment is harsh; signals to and from mobile units are subject to *Rayleigh fading* and *specular multipath* which can lead to *intersymbol interference* in digital transmission and signal drop-outs in analog transmission.
- In suburban and rural environments, terrain effects (hills and valleys) can cut-off service to large areas.
- Little effort is being expended currently in the area of improving signal quality other than digital encoding which increases bandwidth requirements in the absence of sophisticated source compression techniques.
- Cellular solutions to the capacity problem will lead to increased interference even with reduced transmit power levels.
- Signal strength, currently the major factor in determining efficient hand-off strategies in cellular systems, can vary significantly leading to a severe hand-off problem where mobile units are assigned to inappropriate cell sites and cross-talk results.
- A technique for improving quality is required which is:
  1. compatible with all modulation types, digital or analog,
  2. compatible with proposed systems for increasing capacity,
  3. and reliable.

SDMA AND WIRELESS COMMUNICATIONS
INCREASING CAPACITY AND QUALITY

THE SDMA SOLUTION

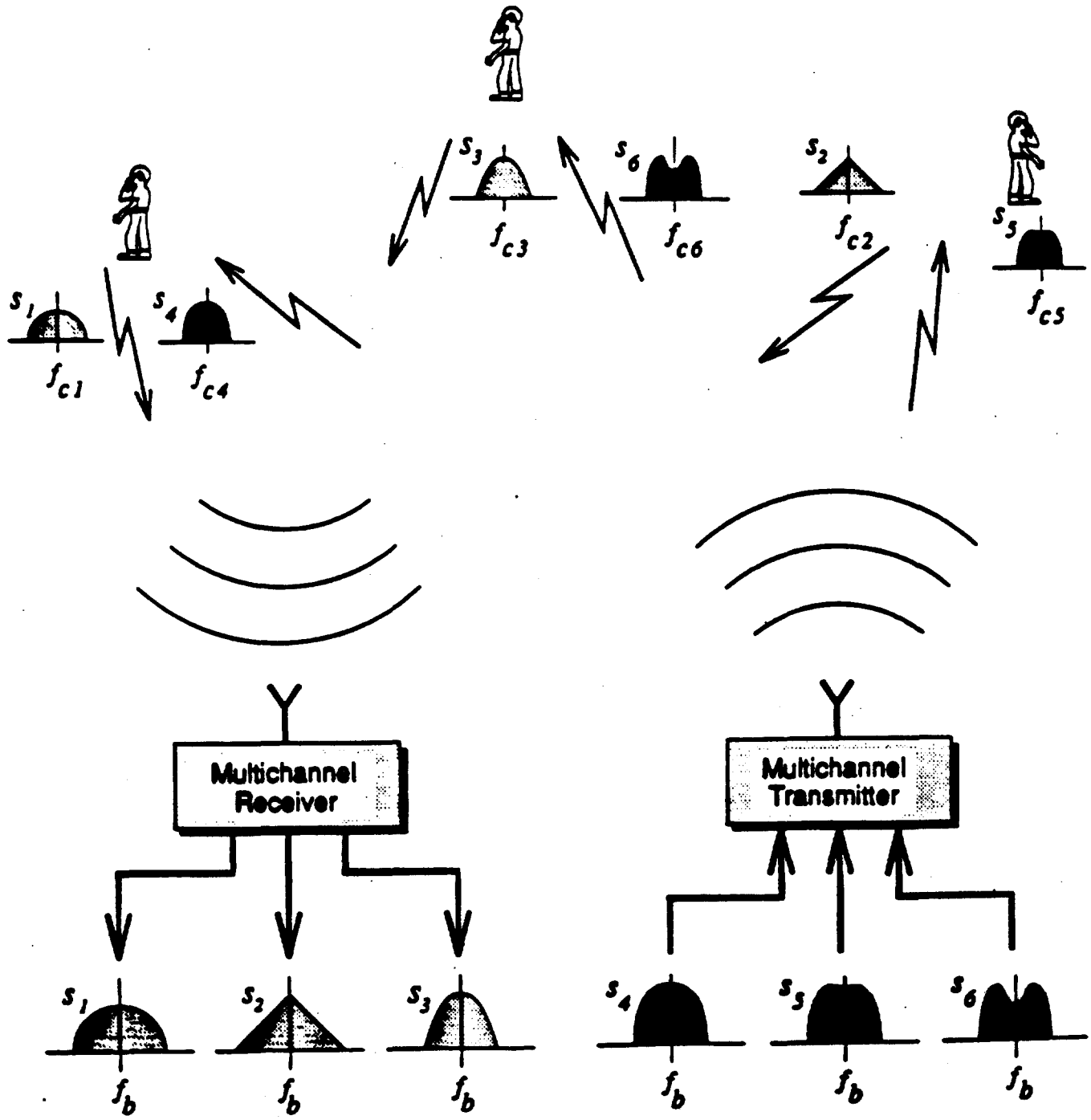
- SDMA (Spatial Division Multiple Access) is essentially a *smart* sectorization technique that locates and tracks *multiple* transmitters in the *same channel (e.g., frequency band).*
- A computationally feasible solution to the normally complex task of tracking multiple cochannel emitters is employed.
- Instead of trying to pack more information into the exponentially decreasing amount of (frequency) spectrum available, SDMA opens up a whole new dimension, *space!*
- SDMA is a technique for increasing *capacity* and *quality* which is:

  1. compatible with all modulation types, digital or analog,
  2. modular and therefore easily expandable,
  3. reliable,
  4. and *realizable!*

- Though compatible with the cellular concept, capacity can be significantly increased without involving more base stations $\Longrightarrow$ increased maintenance and lease costs need not be incurred.

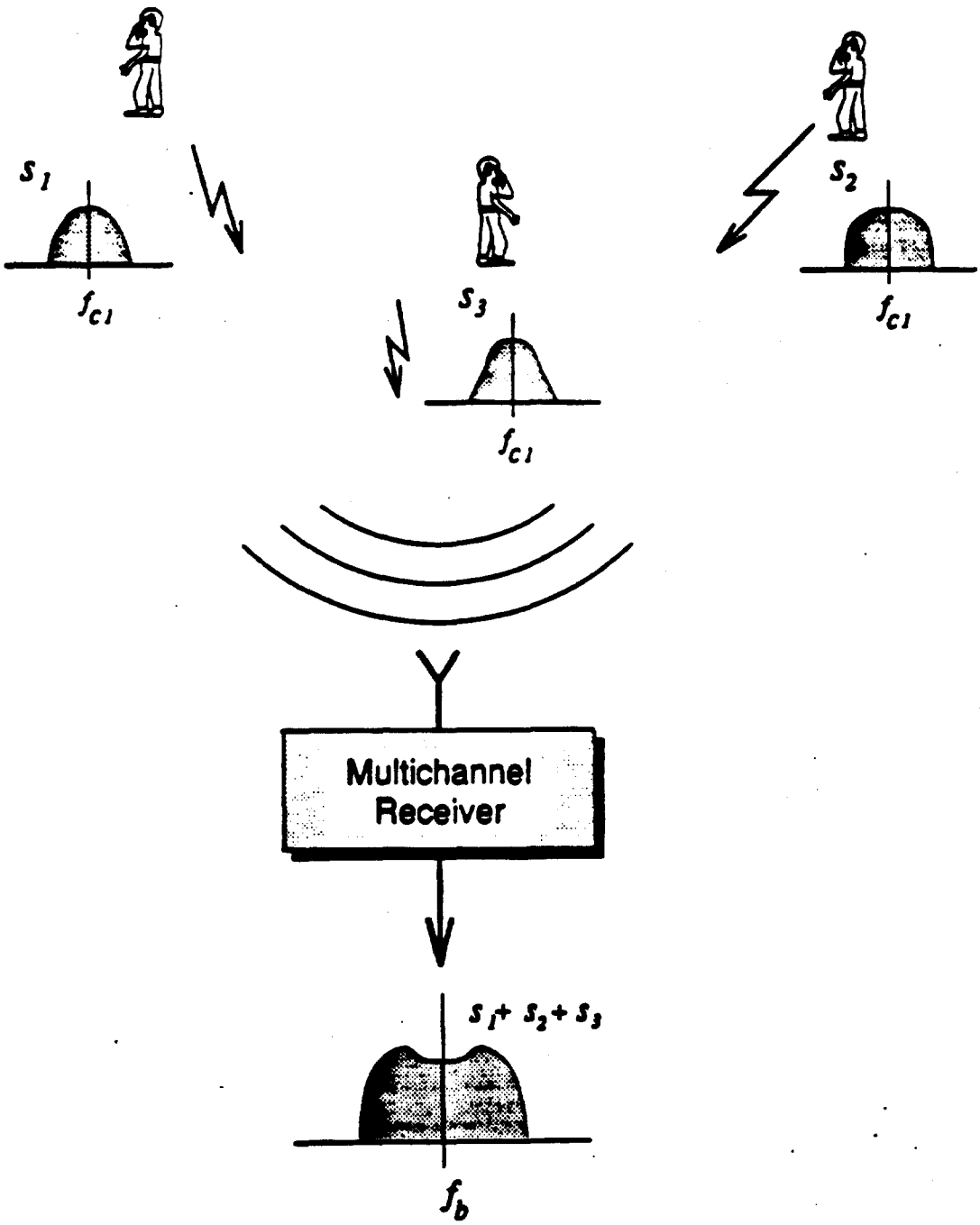
FREQUENCY DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

Frequency Division Multiple Access Communication



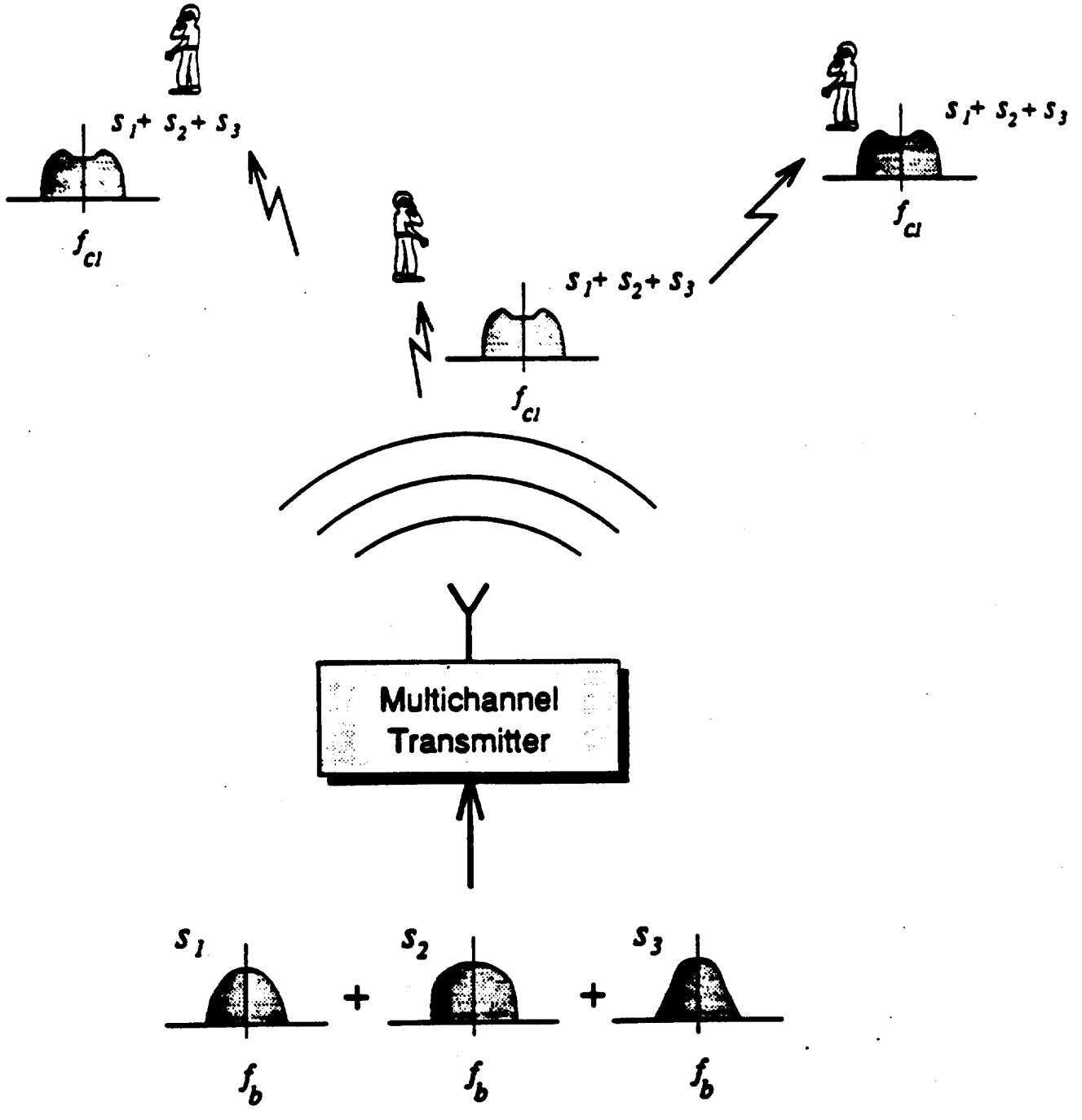
FREQUENCY DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

FDMA and Cochannel Interference



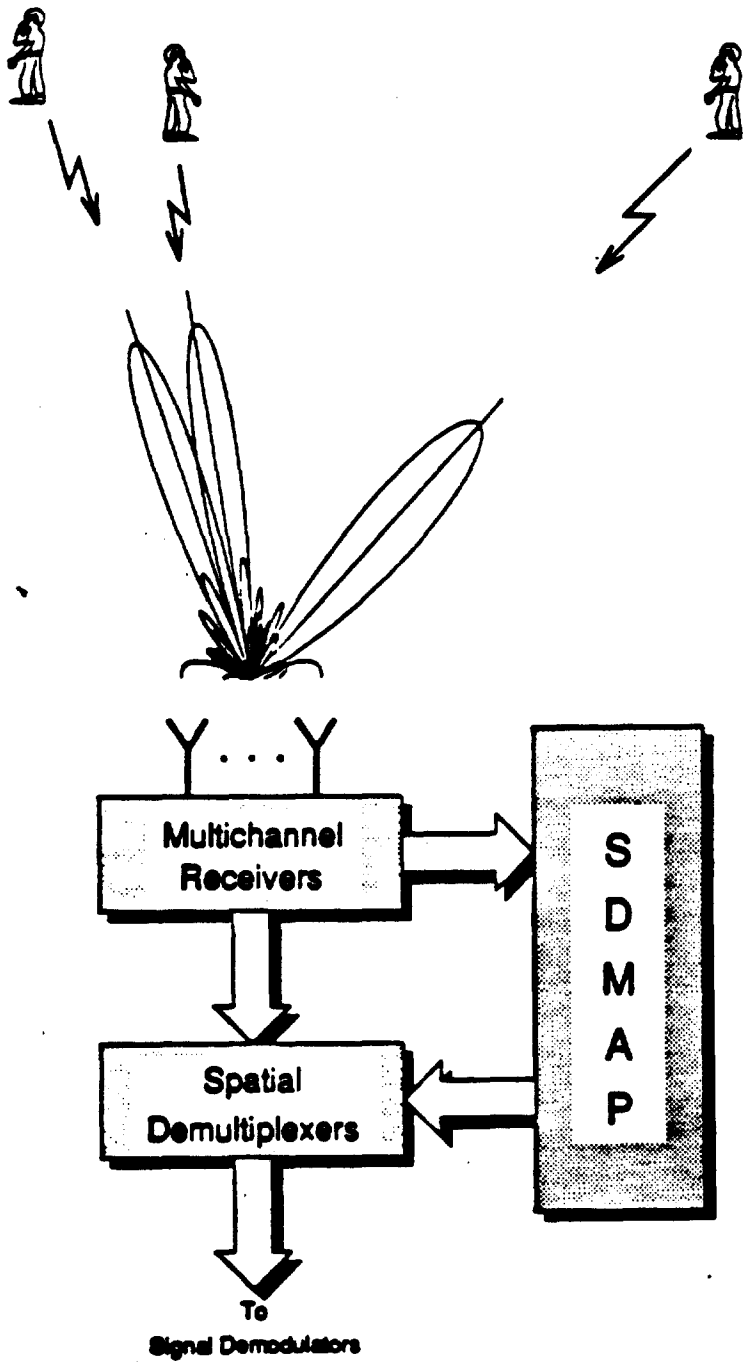
FREQUENCY DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

FDMA and Cochannel Interference



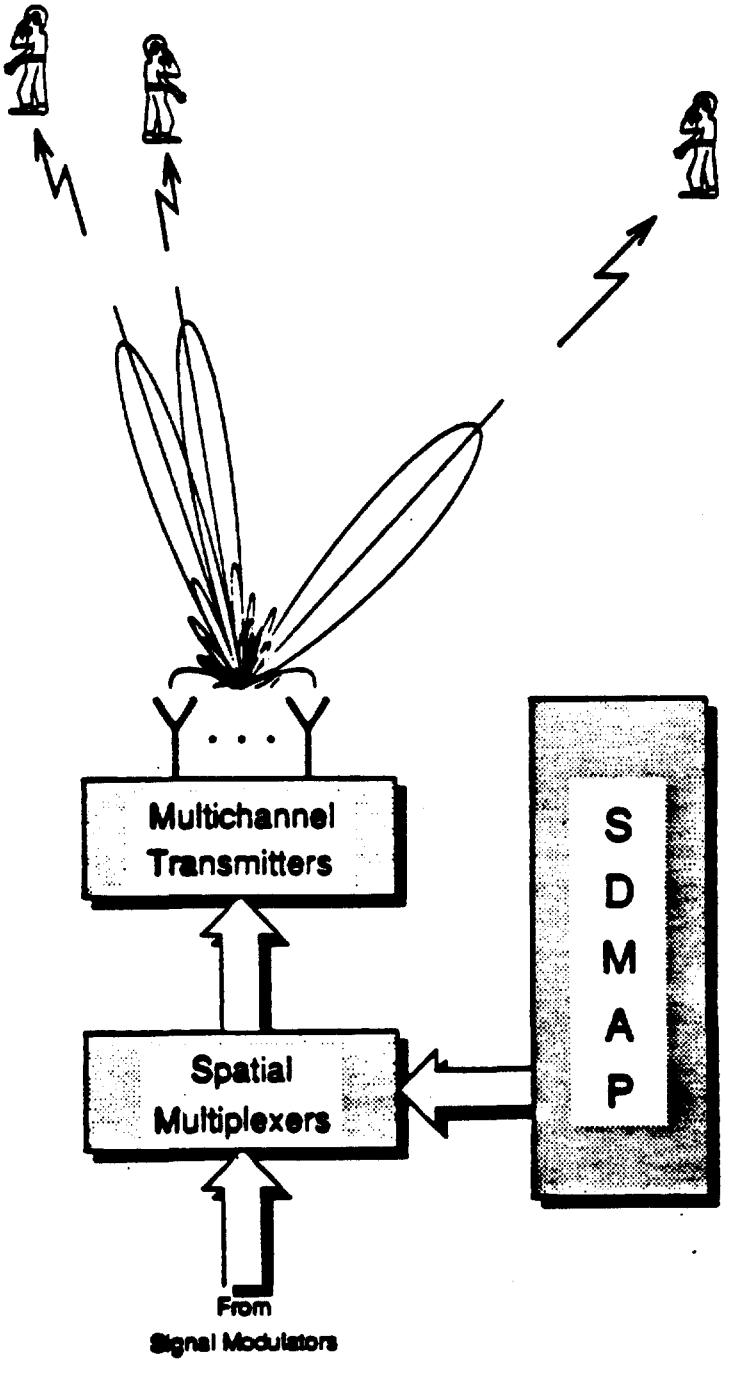
SPATIAL DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

Spatial Division Multiple Access Reception



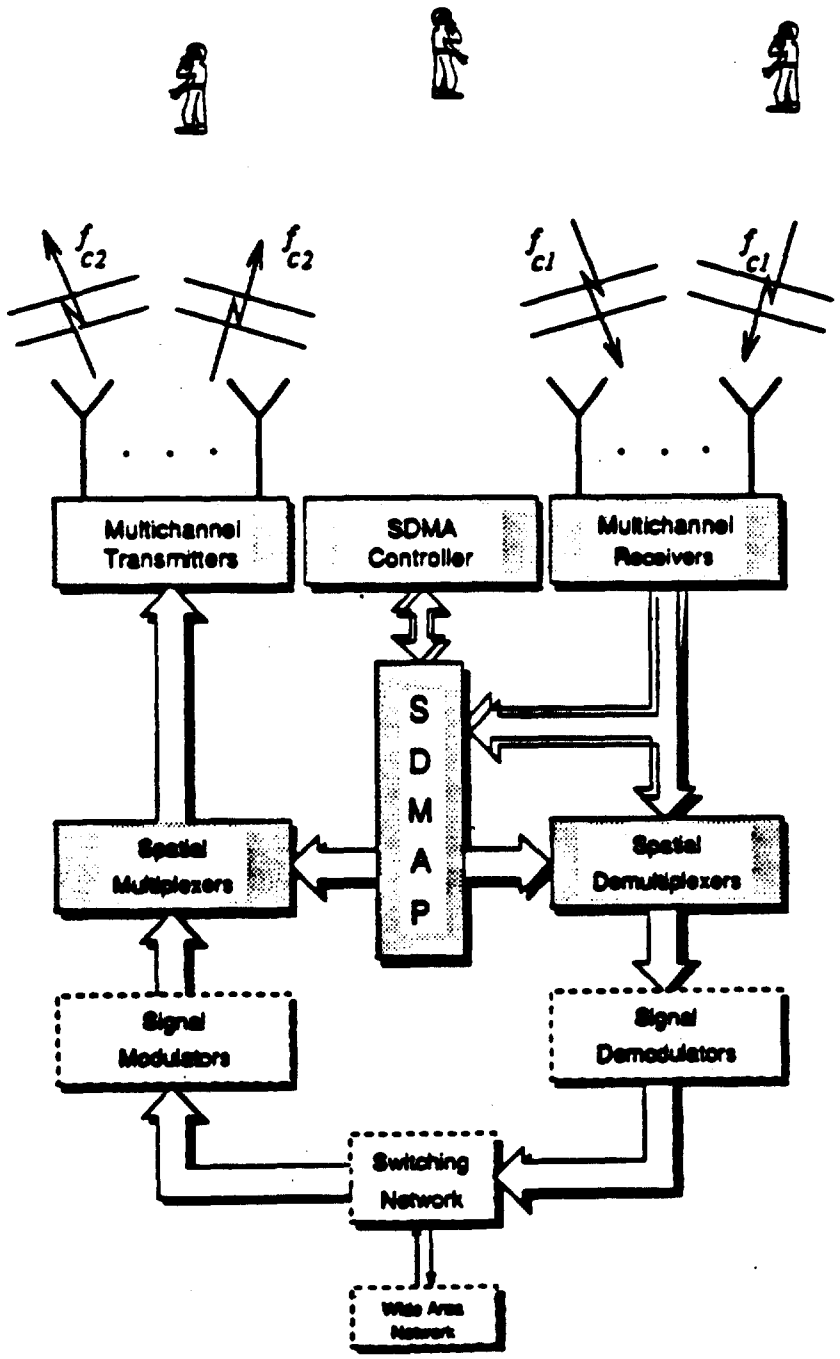
SPATIAL DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

Spatial Division Multiple Access Transmission



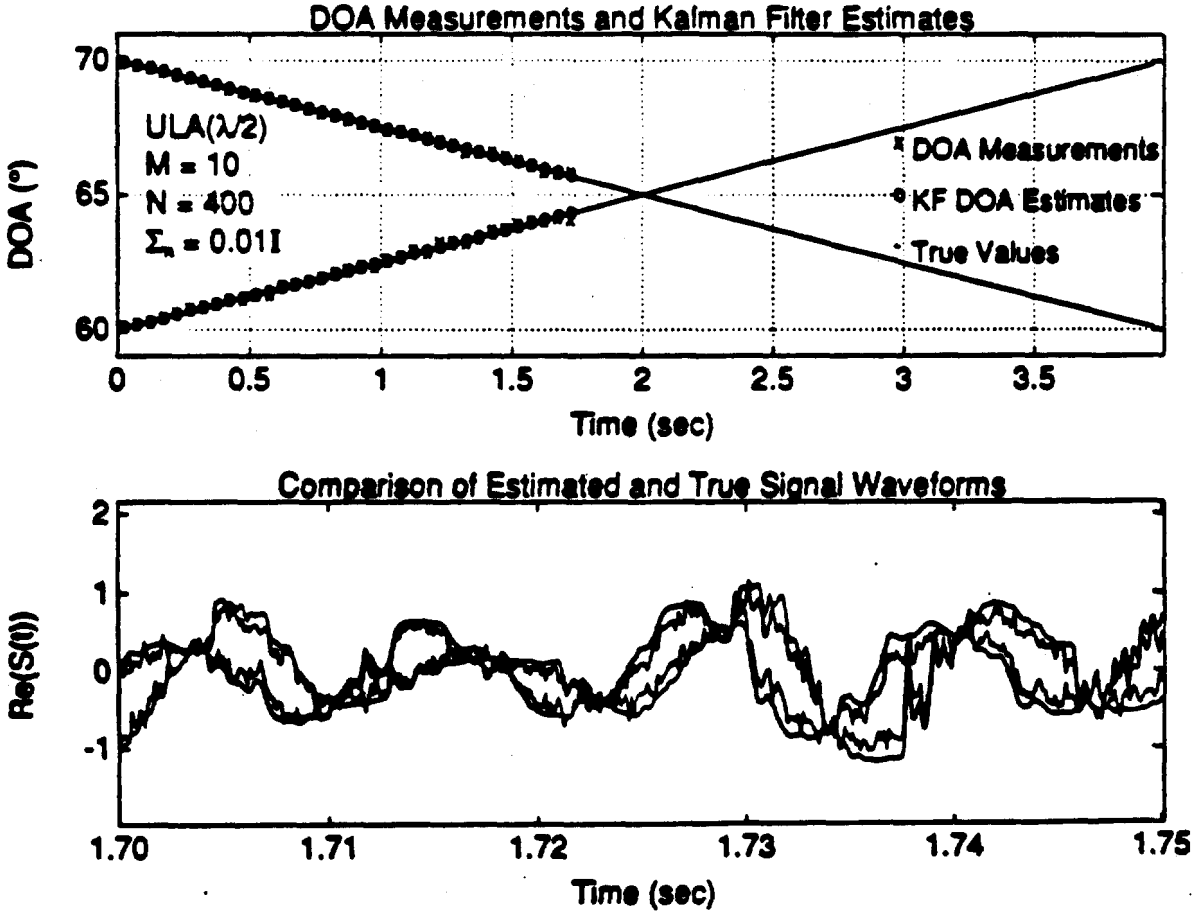
SPATIAL DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

Spatial Division Multiple Access System



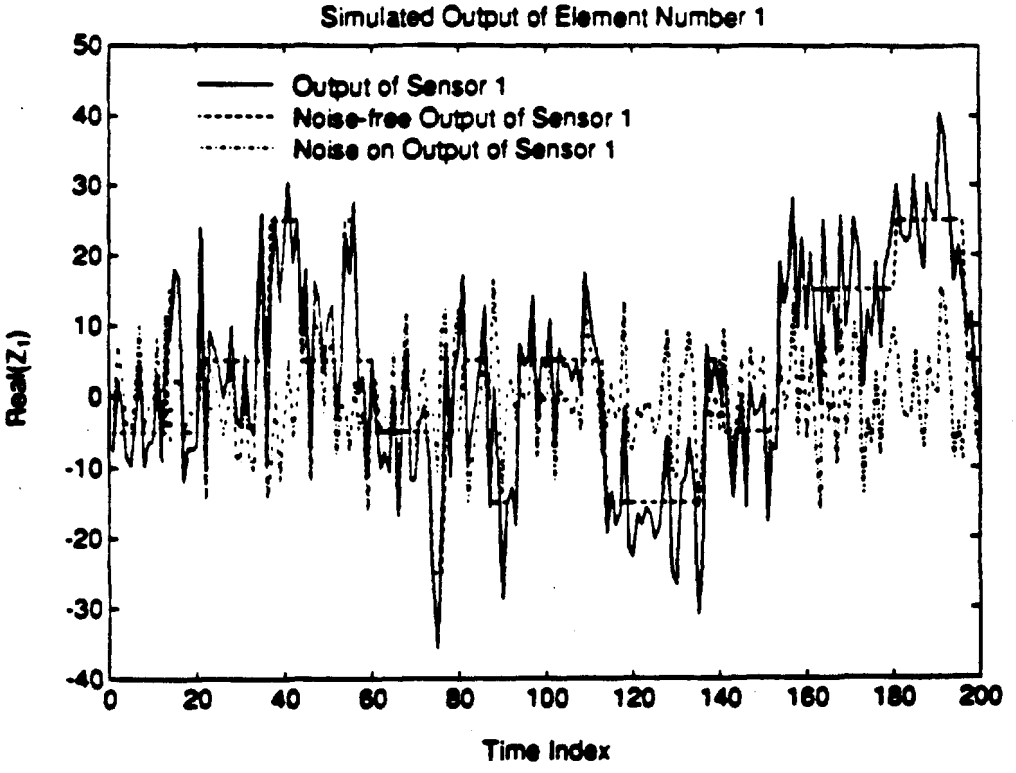
SPATIAL DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

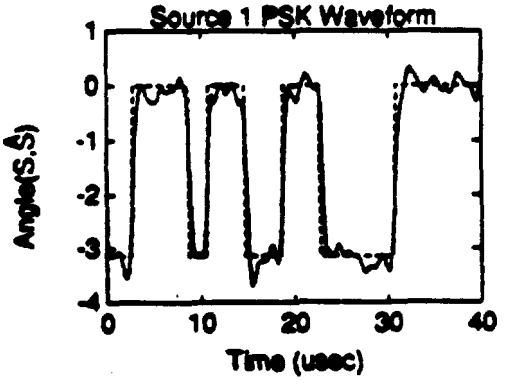
SDMA DOA Tracking and Signal Copy with Severe Rayleigh Fading

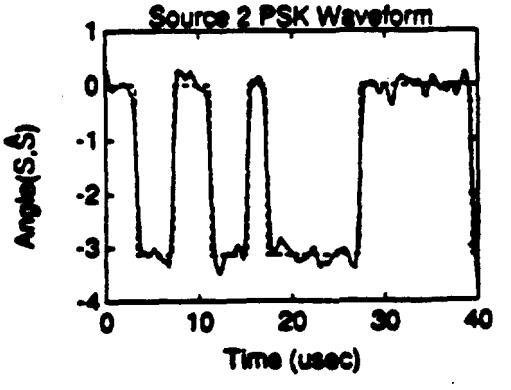


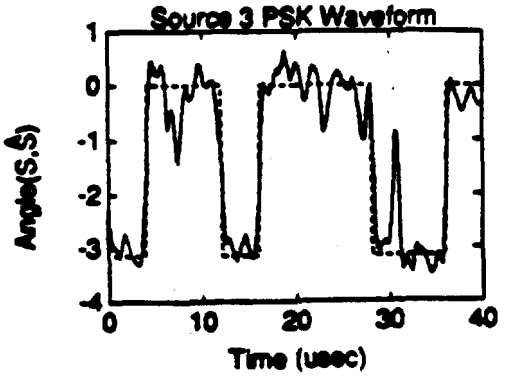
SPATIAL DIVISION MULTIPLE ACCESS
WIRELESS COMMUNICATION SYSTEMS

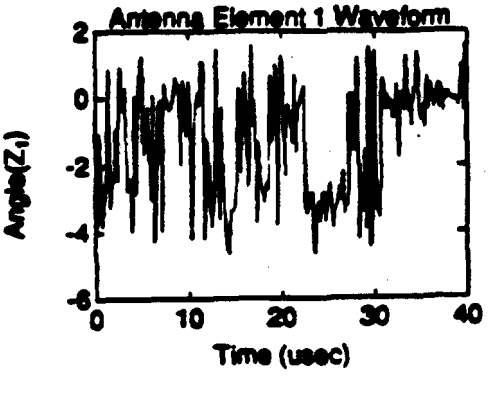
Compatibility of SDMA and Digital Transmission







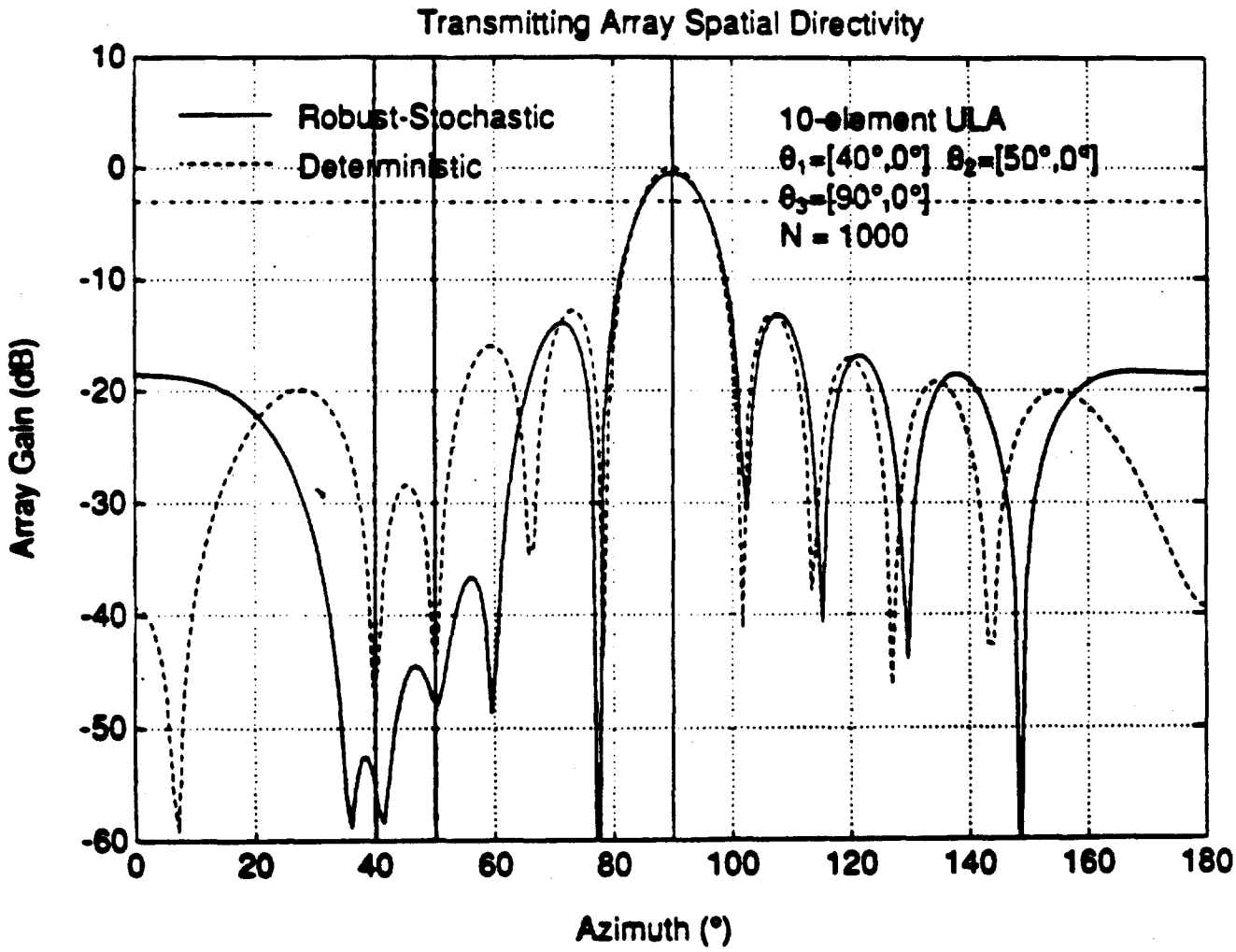




APPLICATION OF SDMA

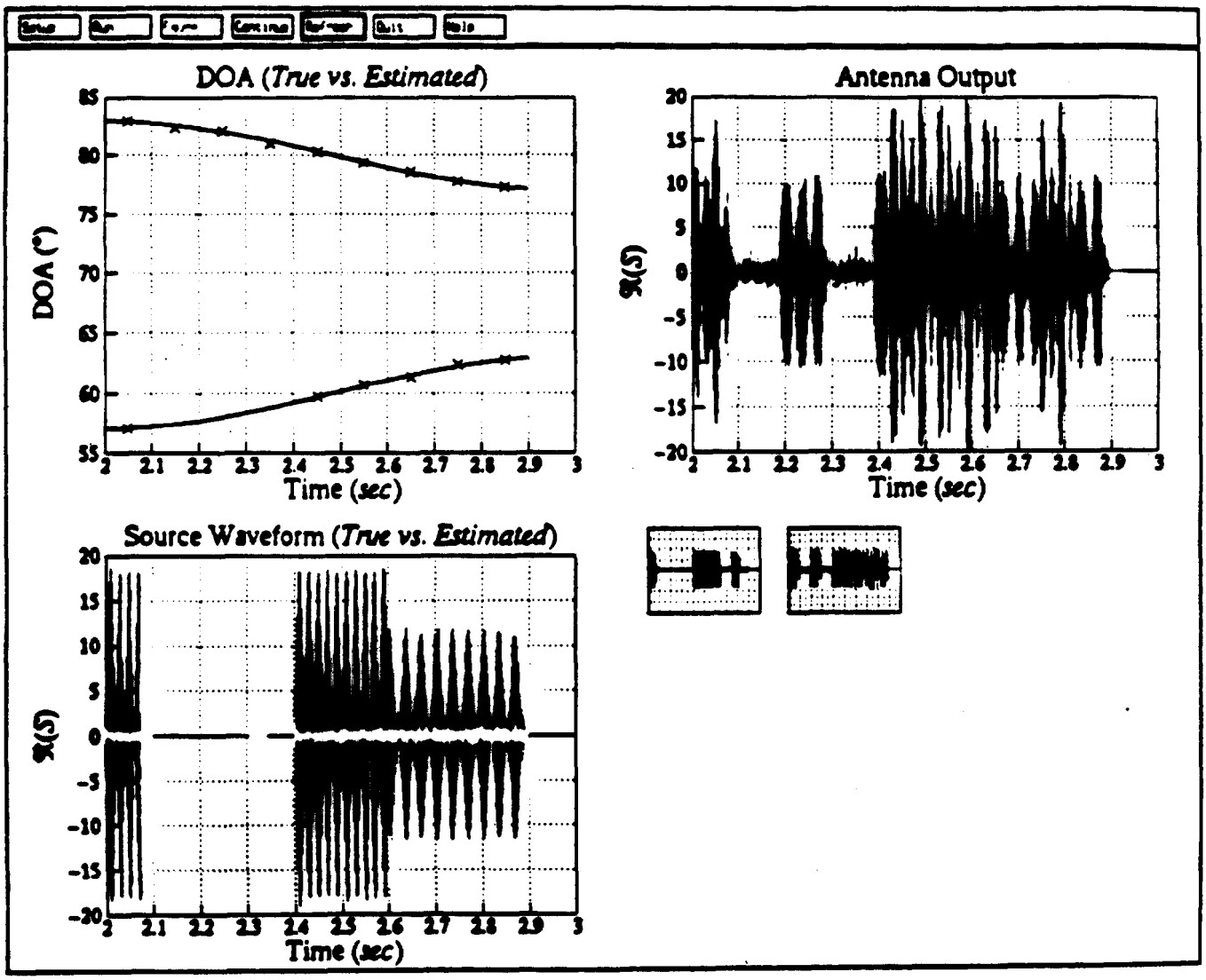
Mobile Communication Systems

ULA Transmitter Spatial Selectivity



SDMA AND WIRELESS COMMUNICATIONS
INCREASING CAPACITY AND QUALITY

REAL-TIME TRACKING AND SIGNAL COPY

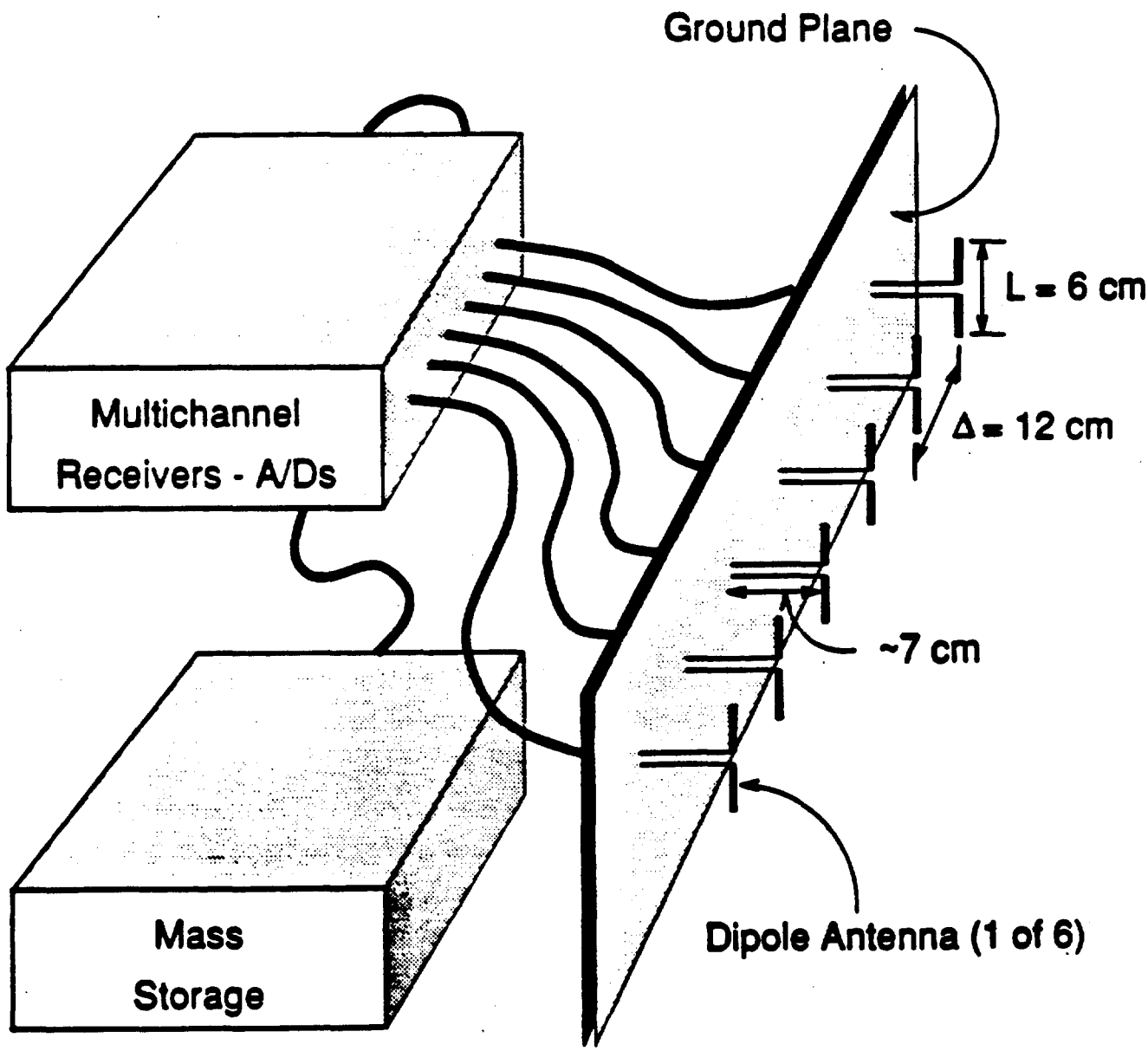


- 4-element ULA($\lambda/2$) - $\approx$ 20 dB SNRs
- Multiple signal DF and signal copy in ($\approx$ 10×) REAL-TIME

SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

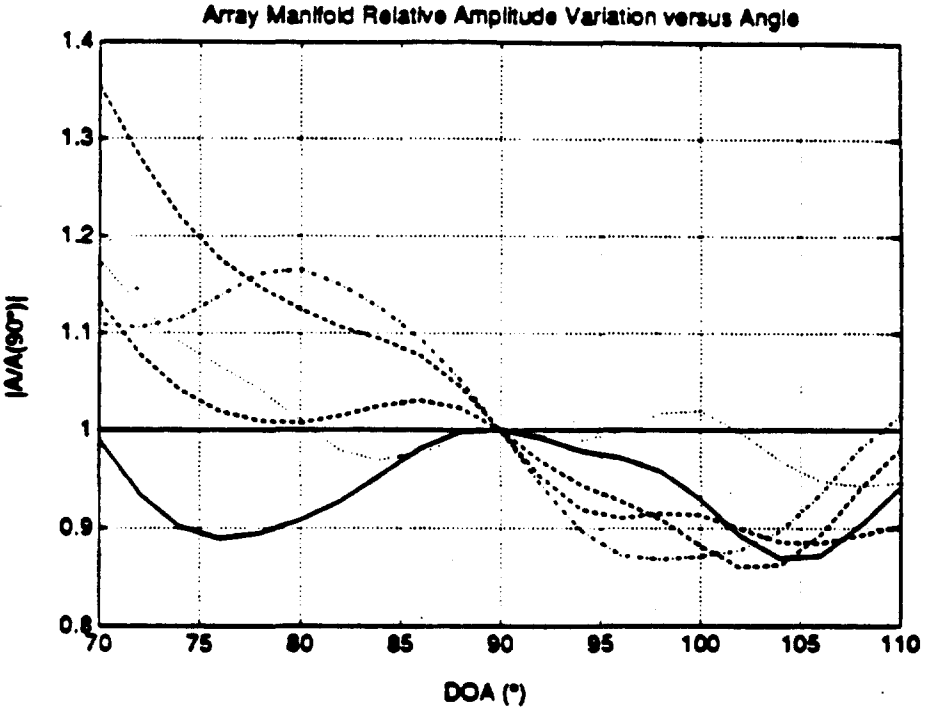
Experimental Apparatus

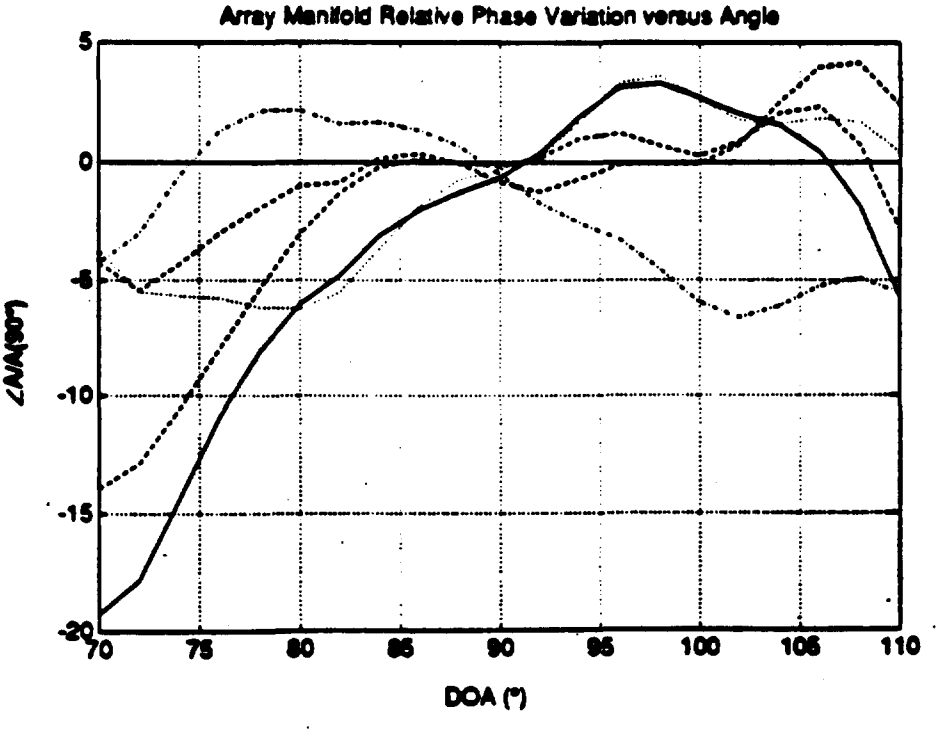


SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

ULA/Array Gain and Phase Deviations

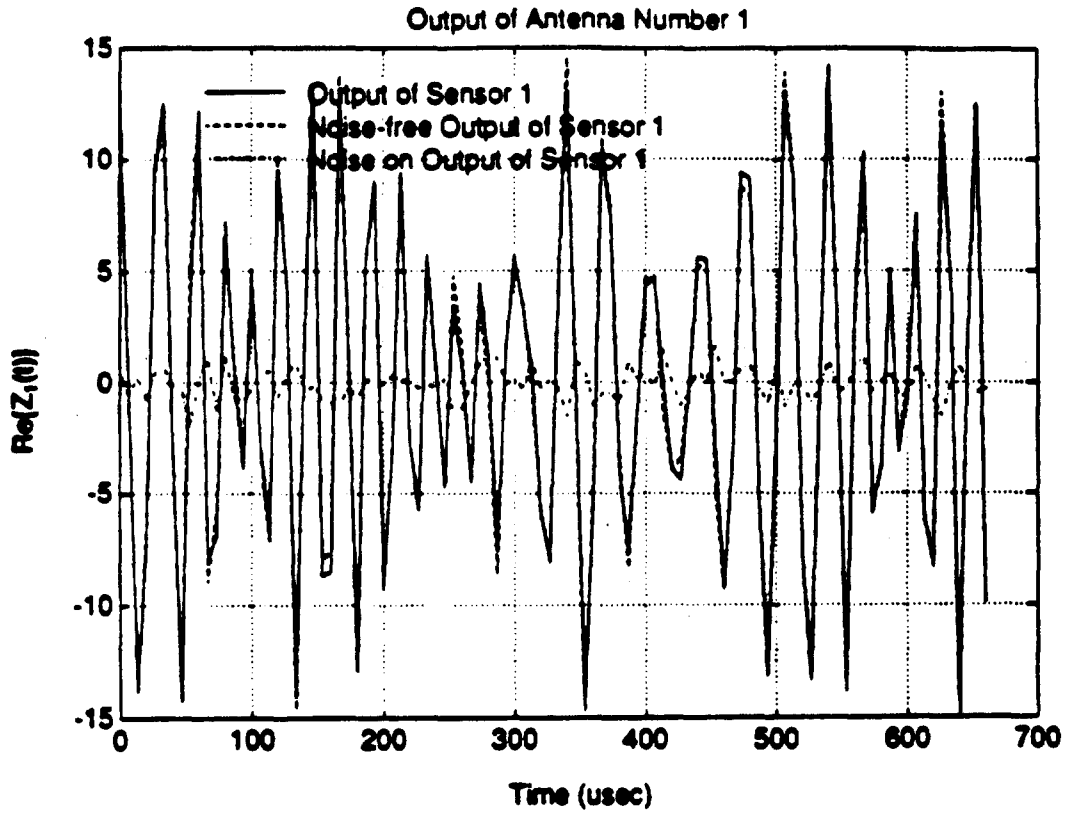




SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Two Sources Closely Spaced ($f_0 = 1200MHz$)

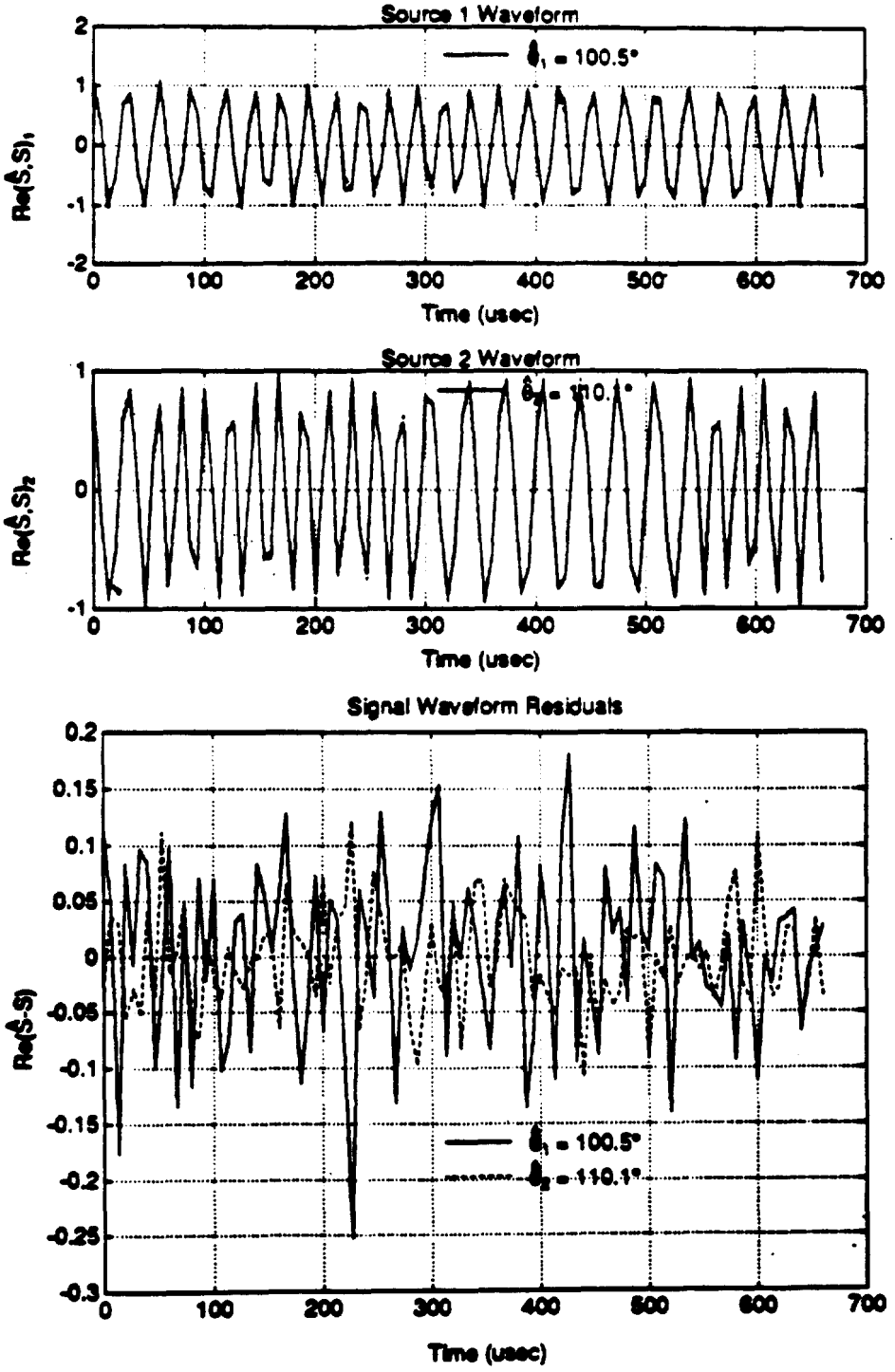


Parameter	Estimate	True Value
$\hat{\theta}_1$	100.5°	100°
$\hat{\theta}_2$	110.1°	110°

SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

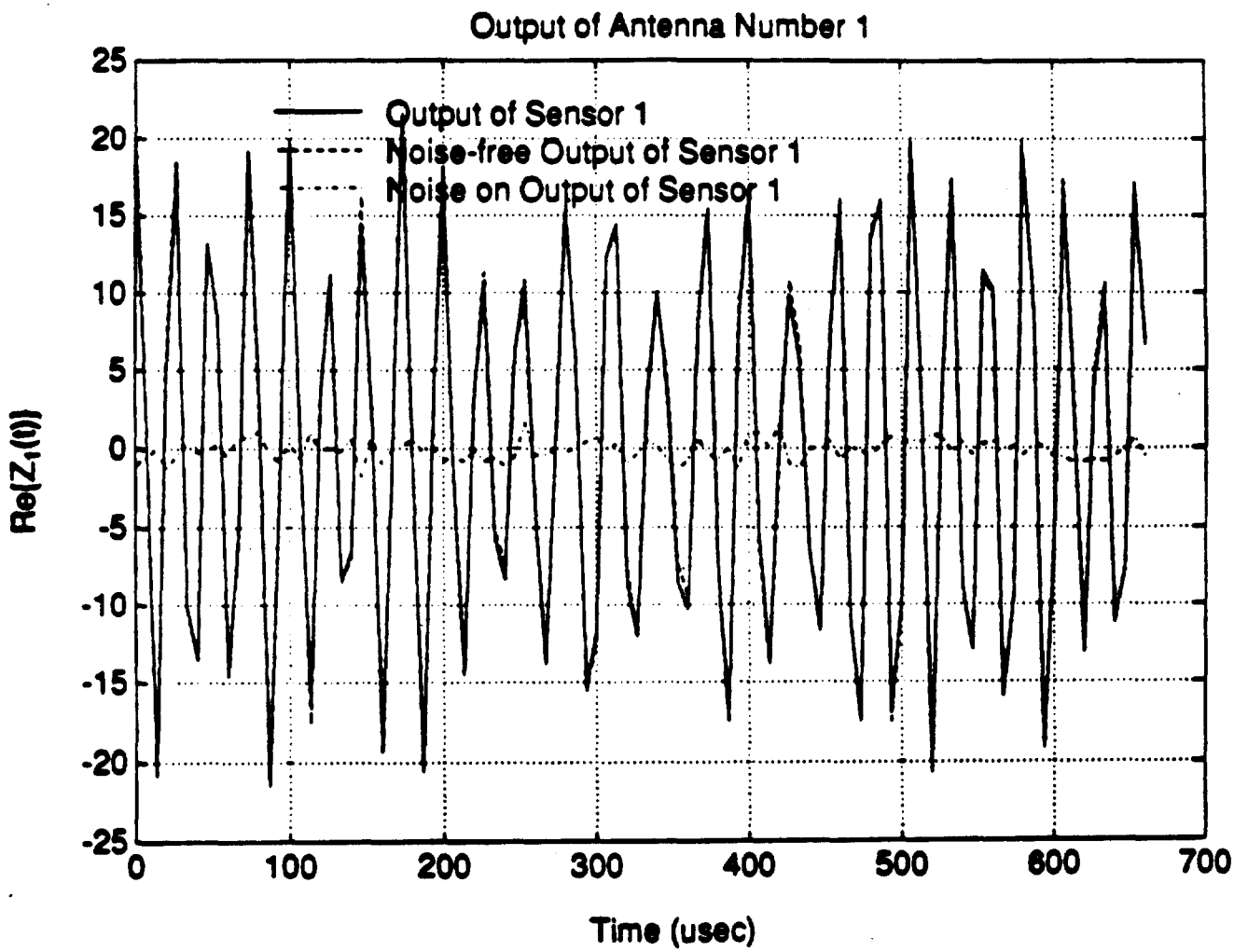
Two Sources Closely Spaced ($f_0 = 1200MHz$)



SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Three Sources ($f_0 = 1200MHz$)

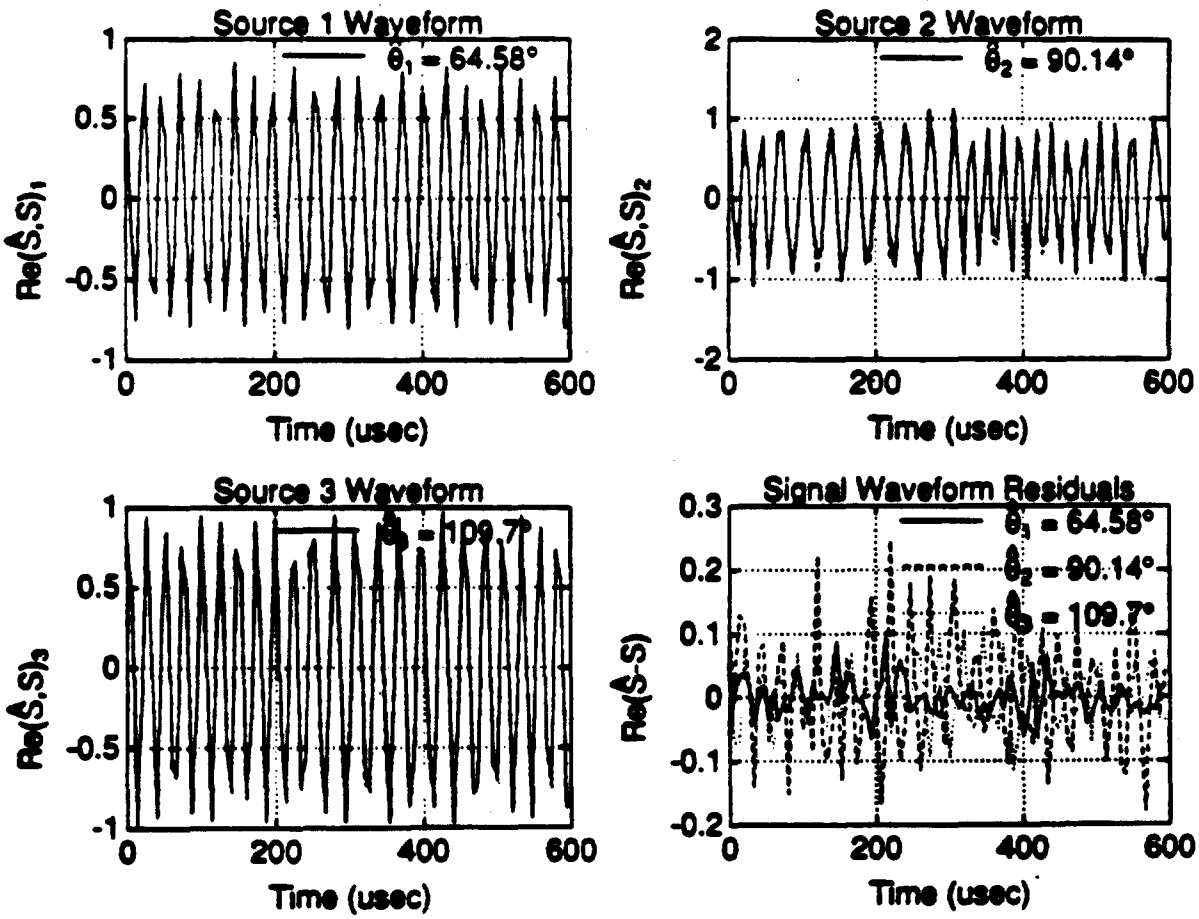


SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Three Sources ($f_0 = 1200MHz$)

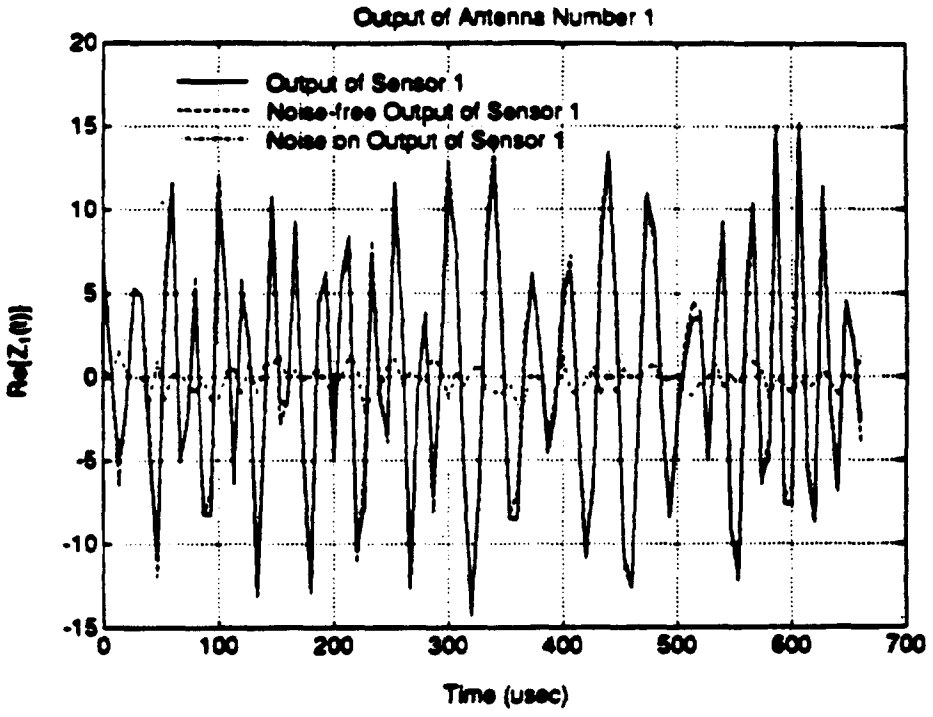
Parameter	Estimate	True Value
$\hat{\theta}_1$	64.6°	65°
$\hat{\theta}_2$	90.1°	90°
$\hat{\theta}_3$	109.7°	110°



SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Two Sources with Rayleigh Fading ($f_0 = 1200MHz$)

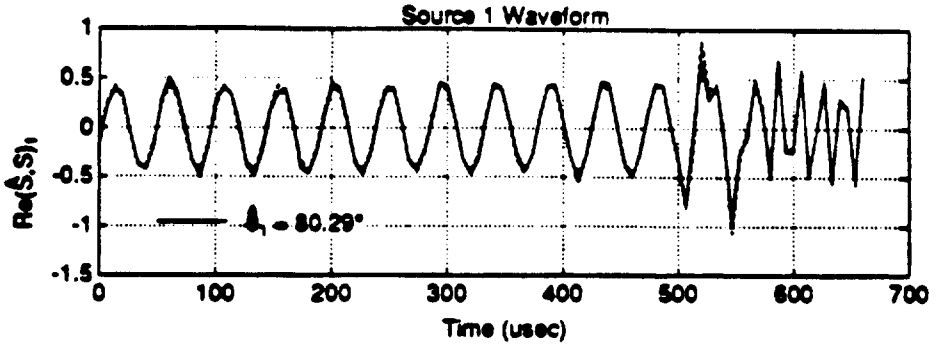


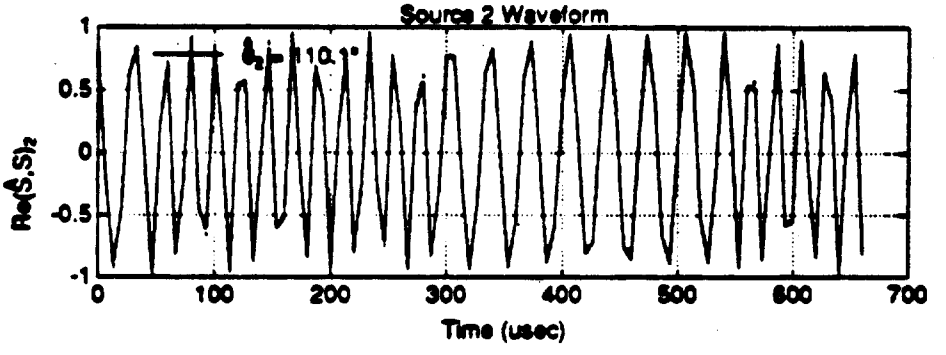
Parameter	Estimate	True Value
$\hat{\theta}_1$	80.3°	78°-80°
$\hat{\theta}_2$	110.1°	110°

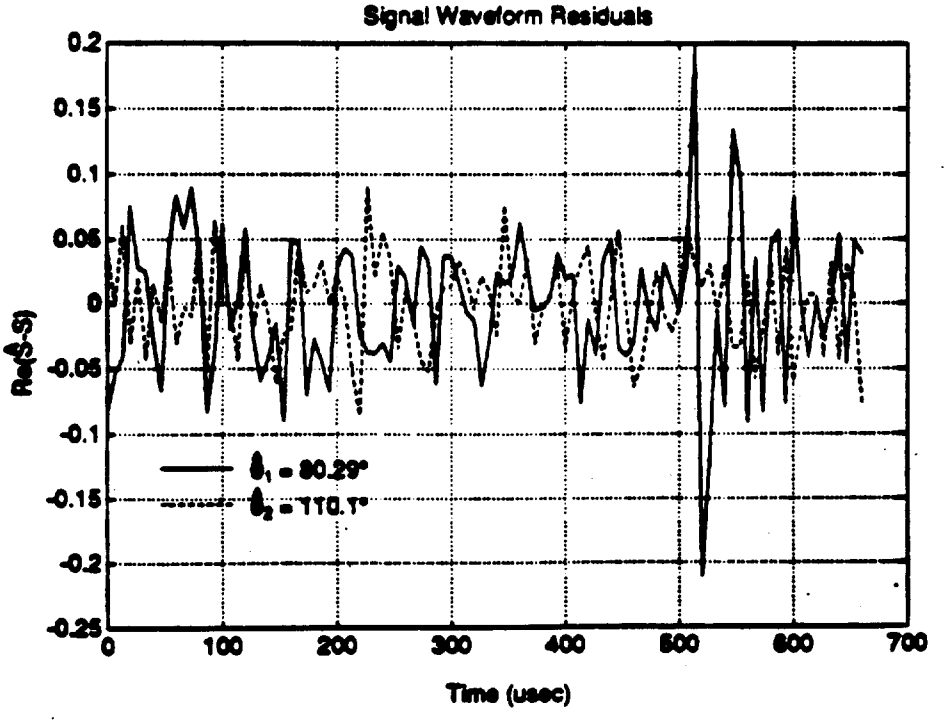
SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Two Sources with Rayleigh Fading ($f_0 = 1200MHz$)



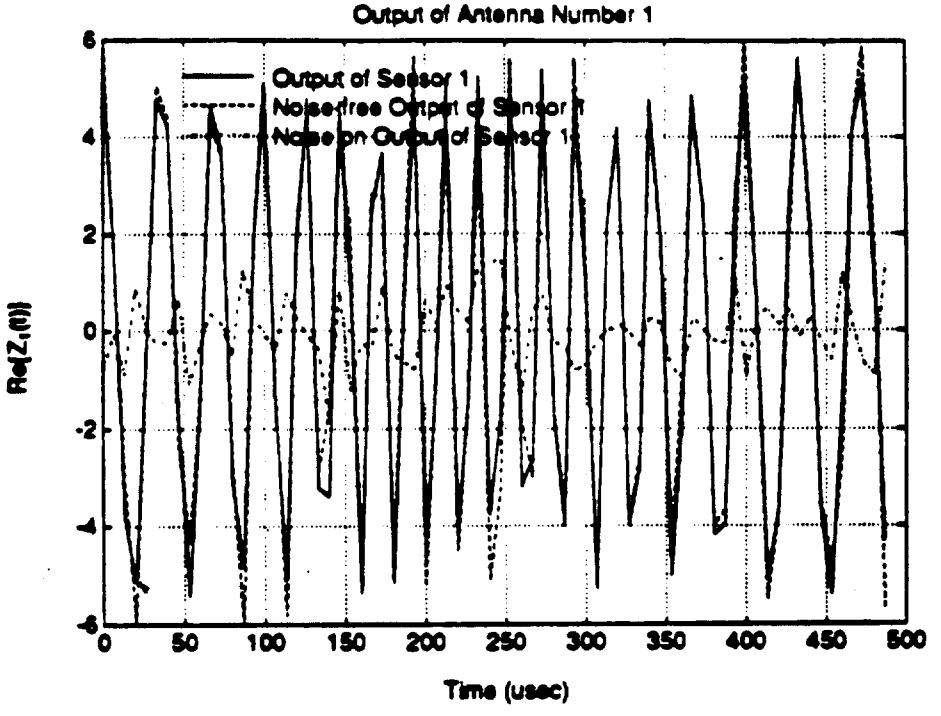




SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Single Source with Multipath ($f_0 = 1200MHz$)

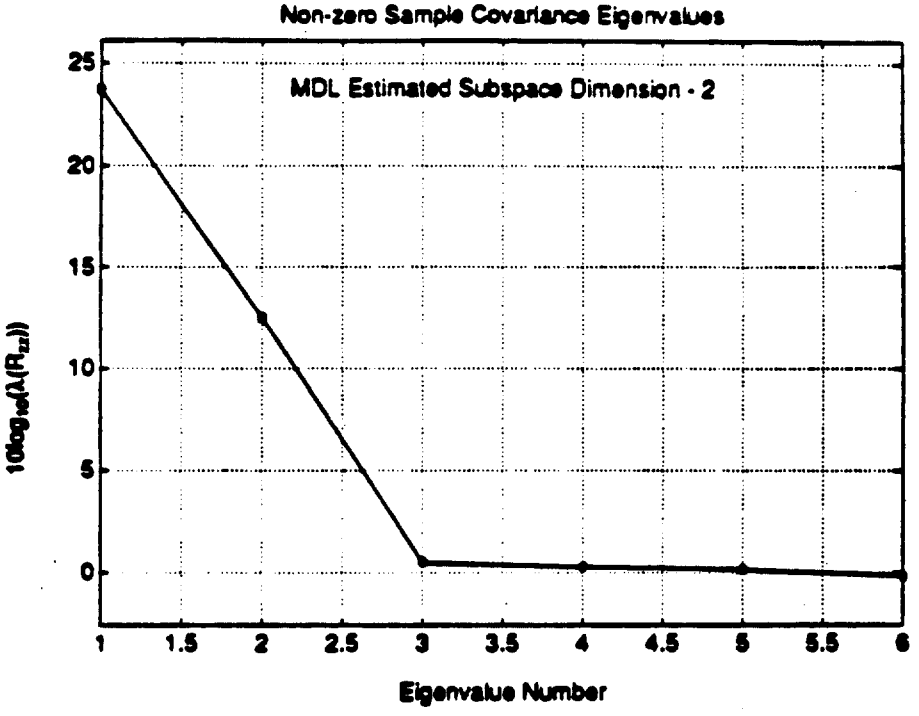


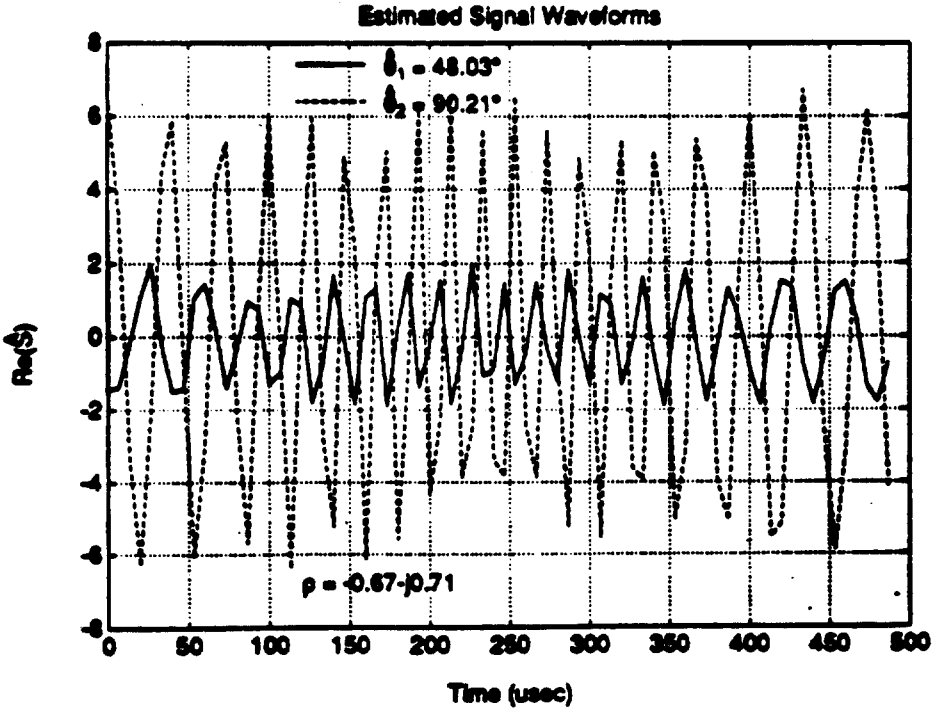
Parameter	Estimate	True Value
$\hat{\theta}_1$	90.2°	90°
$\hat{\theta}_2$	48.0°	$\approx 45°$

SDMA EXPERIMENTAL RESULTS

Anechoic Chamber DF and Signal Copy

Single Source with Multipath ($f_0 = 1200MHz$)





SDMA AND WIRELESS COMMUNICATIONS
INCREASING CAPACITY AND QUALITY

Summary of Key Points

- Benefits from implementation of the SDMA system include:
  - o significant improvement in full-duplex communication link *capacity* and *quality* by establishing *spatio-frequency channels* which
    - — allow multiple wireless units to occupy the same frequency band at the same time
    - — make more efficient use of transmitter power and better received signal quality by *beamforming* on transmit
    - — and increase signal-to-noise ratio (SNR) and decrease cochannel interference at the base site by *smart beamforming* on receive
  - o elimination of *dead zones* within service areas
  - o elimination of Doppler frequency offsets due to relative transmitter-receiver motion
  - o decrease in *frequency reuse factor* in cellular systems $\Longrightarrow$ substantial increase in capacity
  - o system flexibility allowing dynamic channel bandwidth allocation.
- SDMA is compatible with both analog and digital modulation, and furthermore can accomodate *dual service* on the *same frequency channel* at the *same time!*
- SDMA system modularity allows capacity and quality to be incrementally increased to meet demand.